Astrobiology, Habitability and the Moon

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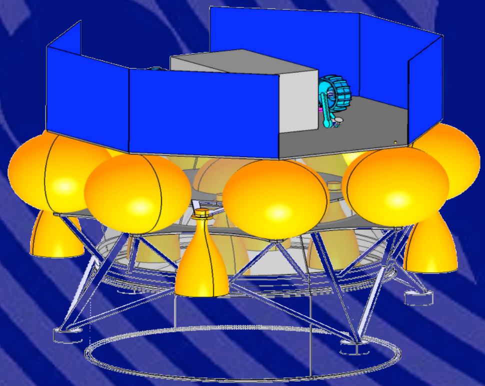

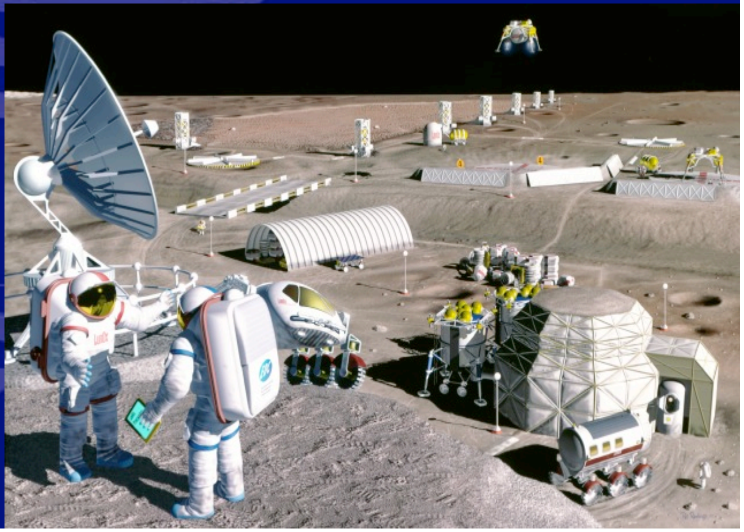

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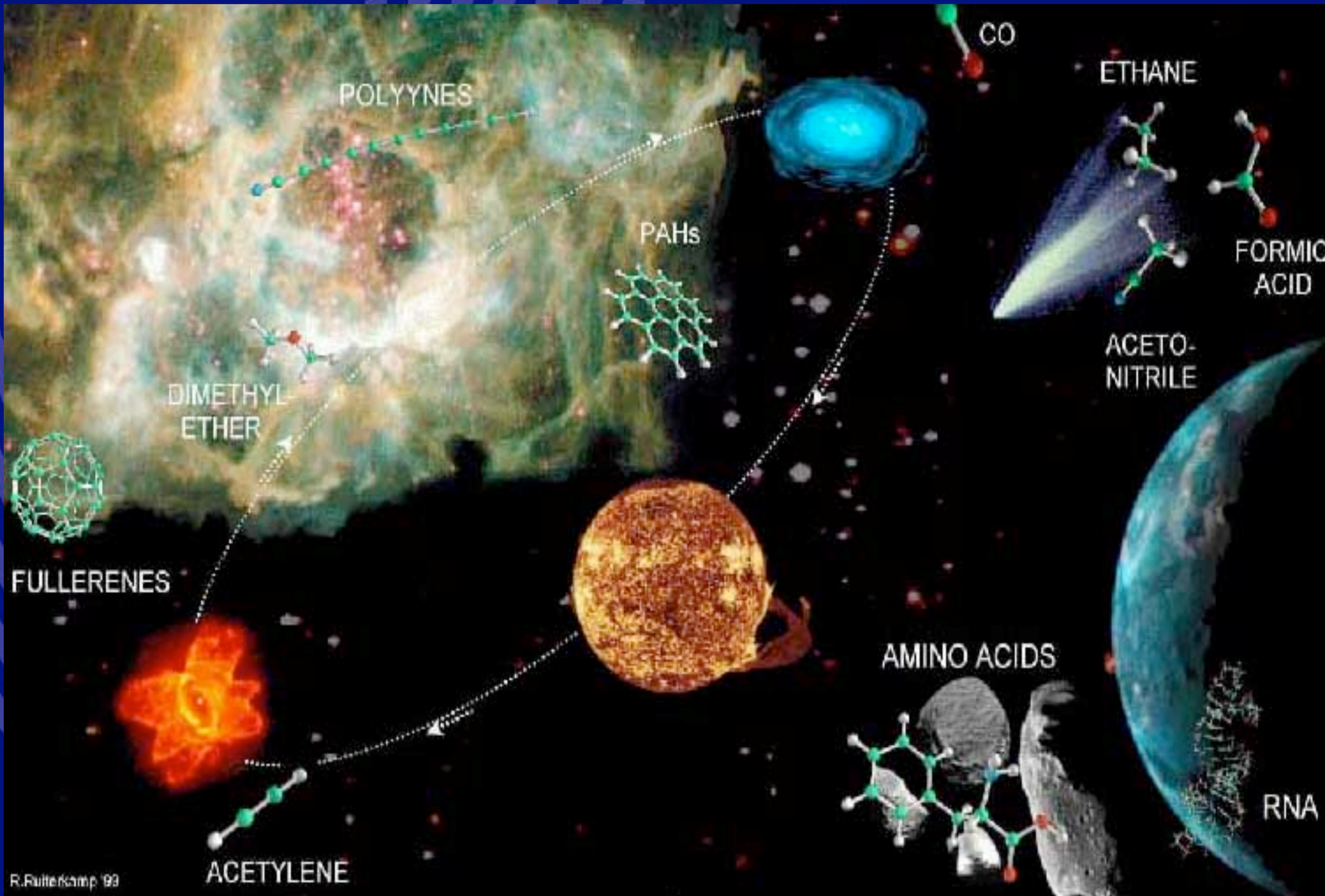


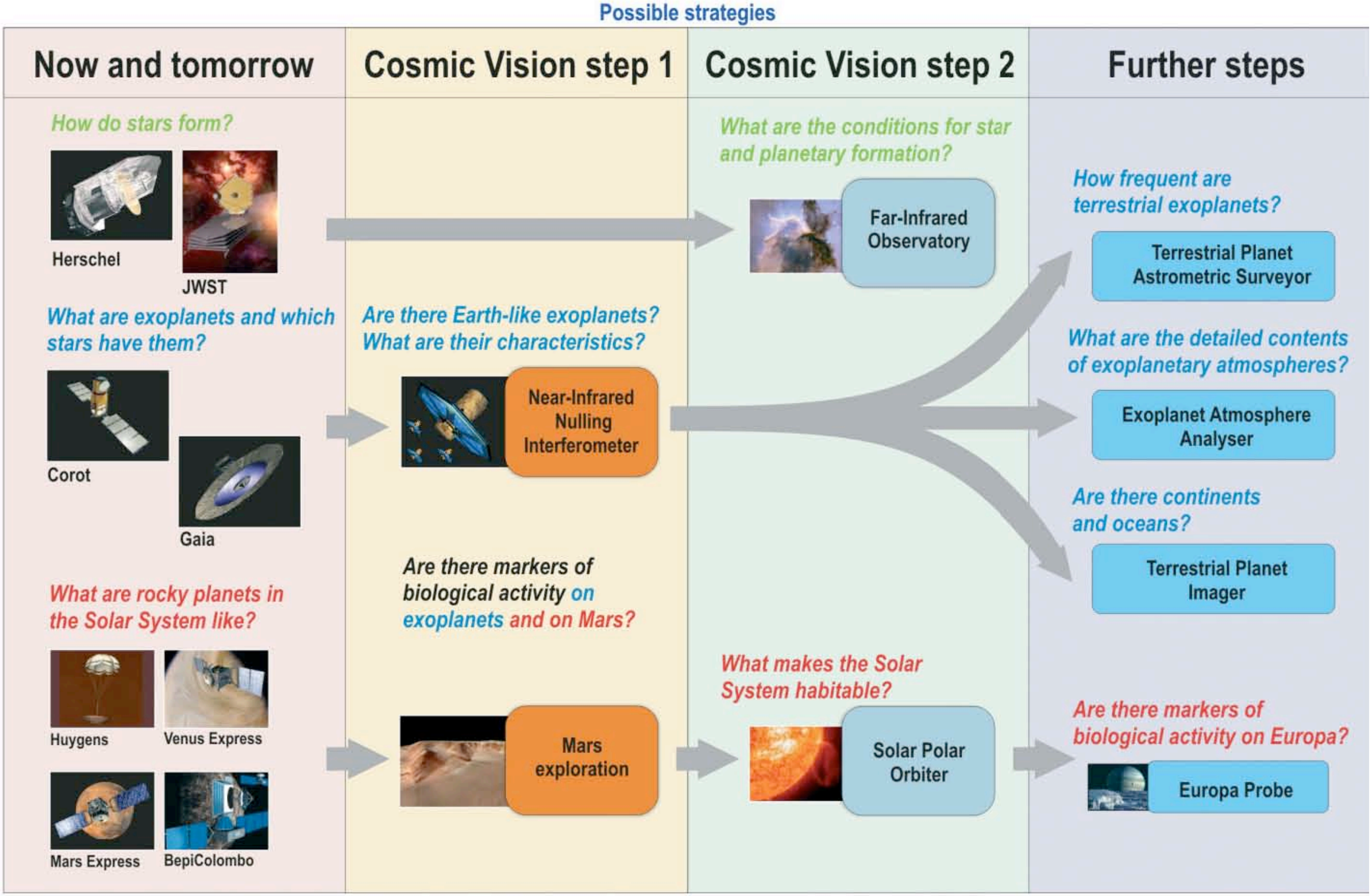
Life: ingredients, habitability, origin, evolution, survival and expansion beyond the cradle planet

BHF 2008

Perspectives for space astrobiology

- Astrochemistry
- Stars and Exoplanets
- Planetary formation
- Sun-planetary connections
- Atmospheres
- Planetary mapping and databases
- Habitability
- Instruments for organics and search for life
- Geochemistry environments
- Subsurface probes
- Interiors (gravimetry, seismology, geodesy)
- Modelling, laboratory and ground support research

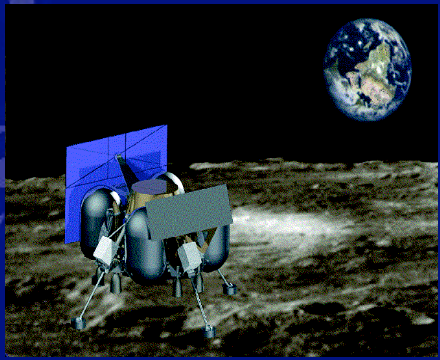
1. What are the conditions for planetary formation and the emergence of life?



IAA Next steps to Moon: What Science and How?

Lunar outposts for exploration on the Moon

- Search for evidence of the origin of the Earth-Moon system
- Determine the history of asteroid and comet impacts on Earth
- Obtain evidence of the Sun's history and its effects on Earth through time
- Search for samples from the Early Earth
- Determine the form, amount, and origin of lunar ice
- Expand life on the Moon, and exploit local resources
- Human exploration enhanced by robots



Exploration architecture

- A proving ground: *Learn to explore* the Moon and beyond
- Transportation systems synergy with SunEarth-L2 and Mars requirements
- Extended robotic & human presence on the Moon : cultural milestone

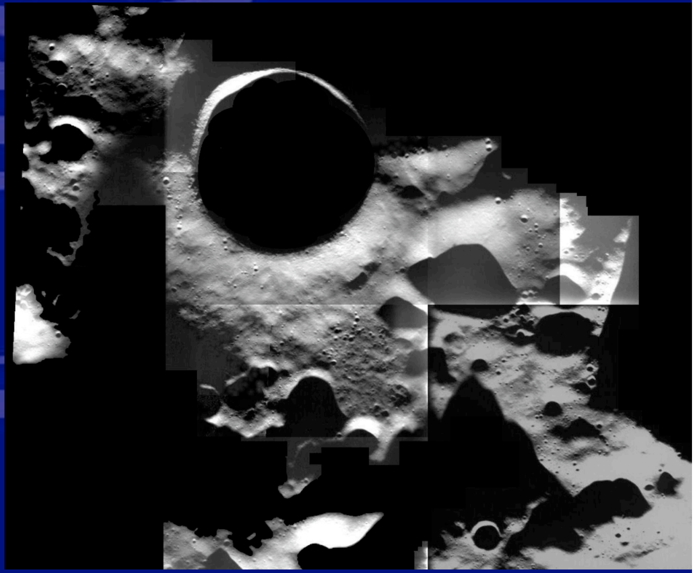
Are organics present in lunar ice deposits ?

Organics from impactors trapped in polar lunar ice

Formation of organic molecules by energetic processing

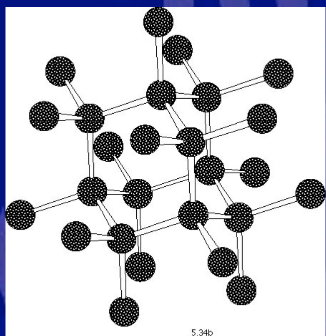
Radiation and thermal cycling in ice can produce complex organic molecules

Radiation dose on the Moon is highly destructive for small organics on the top meter

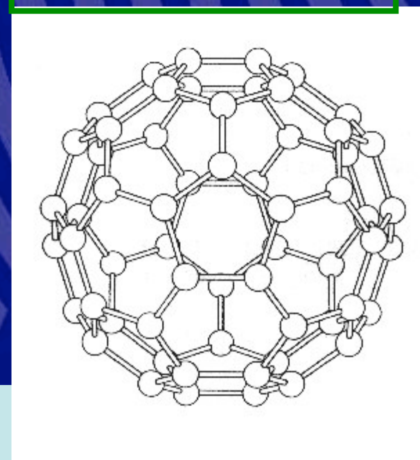


Large carbonaceous molecules in space

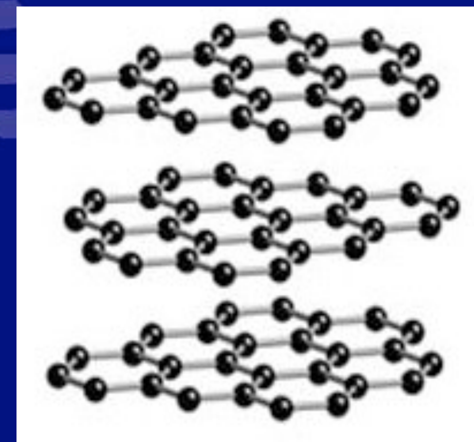
Diamond <<



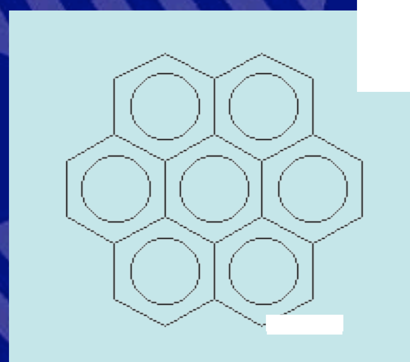
Fullerenes ~ 0.5 %



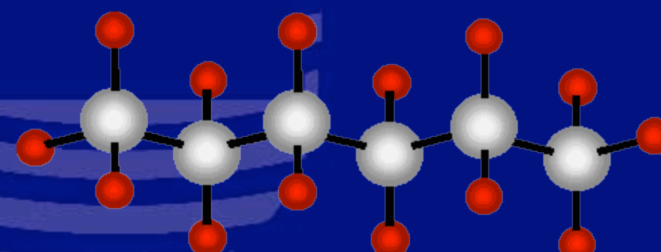
Graphite ?



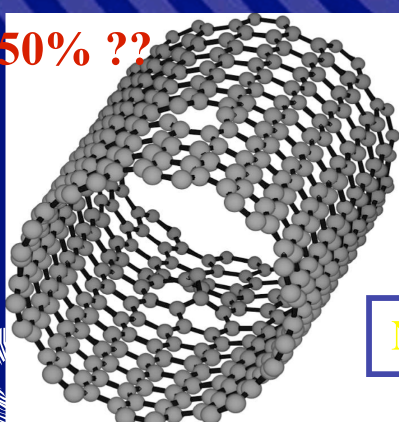
PAHs ~ 15 %



C-chains ~ 0.1%



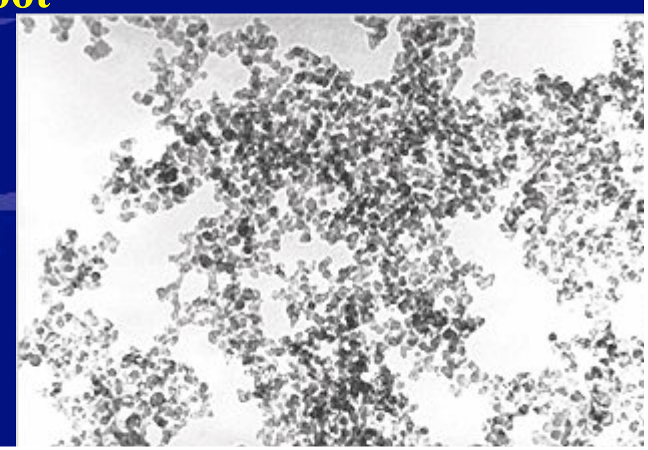
> 50% ??



Nanotubes

C-onions

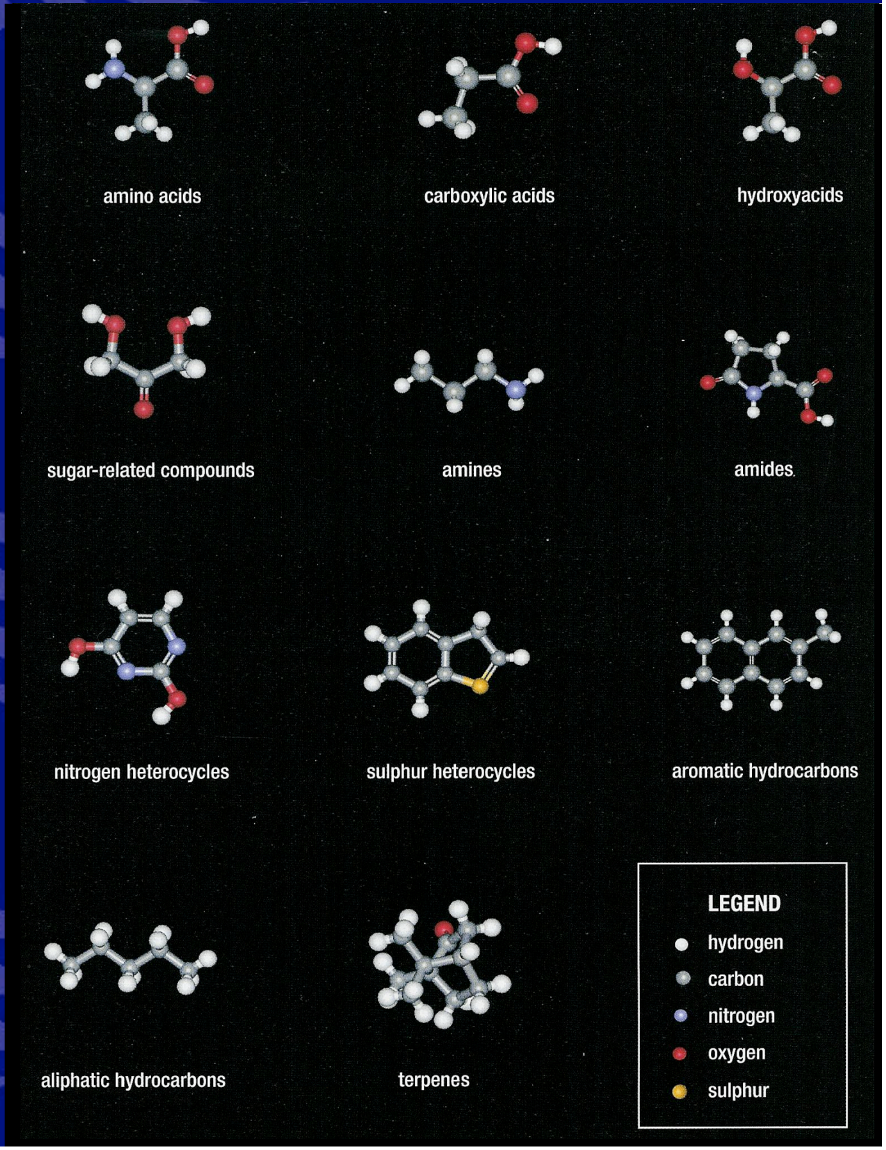
Soot



Organic compounds in the Murchison meteorite

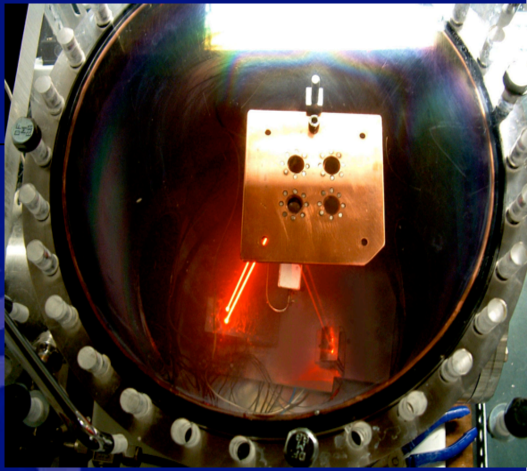
Sephton 2002

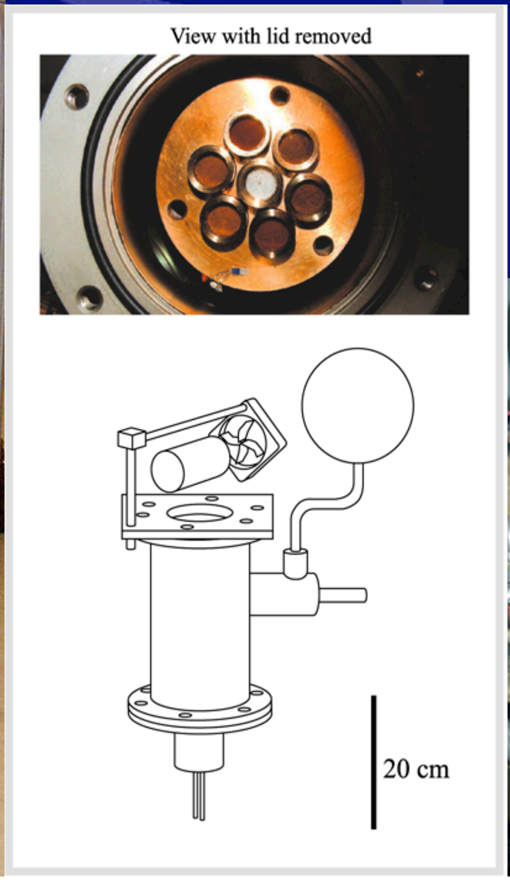
Compound Class	Concentration(ppm)
CO_2	106
CO	0.06
CH_4	0.14
NH_3	19
Aliphatic hydrocarbons	12-35
Aromatic hydrocarbons	15-28
Amino Acids	60
Monocarboxylic acids	332
Dicarboxylic acids	26
α-hydroxycarboxylic acids	14
Polyols (sugar-related)	~24
Basic N-heterocycles	0.05-0.5
Purines	1.2
Pyrimidines	0.06
Amines	8
Urea	25
Benzothiophenes	0.3
Alcohols	11
Aldehydes	11
Ketones	16



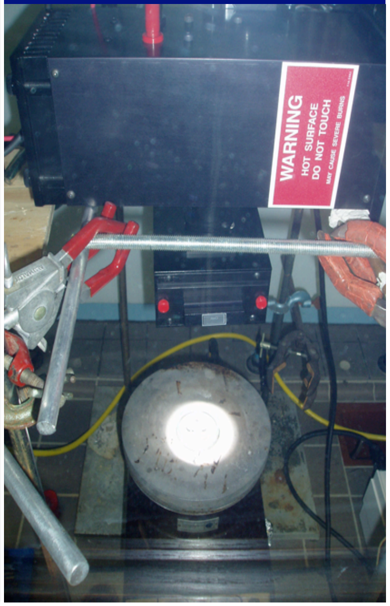
Moon-Mars simulations

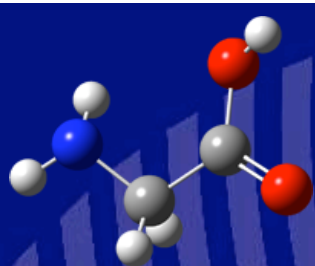
Testing the survival of organic matter and microbes under Moon-Mars surface conditions





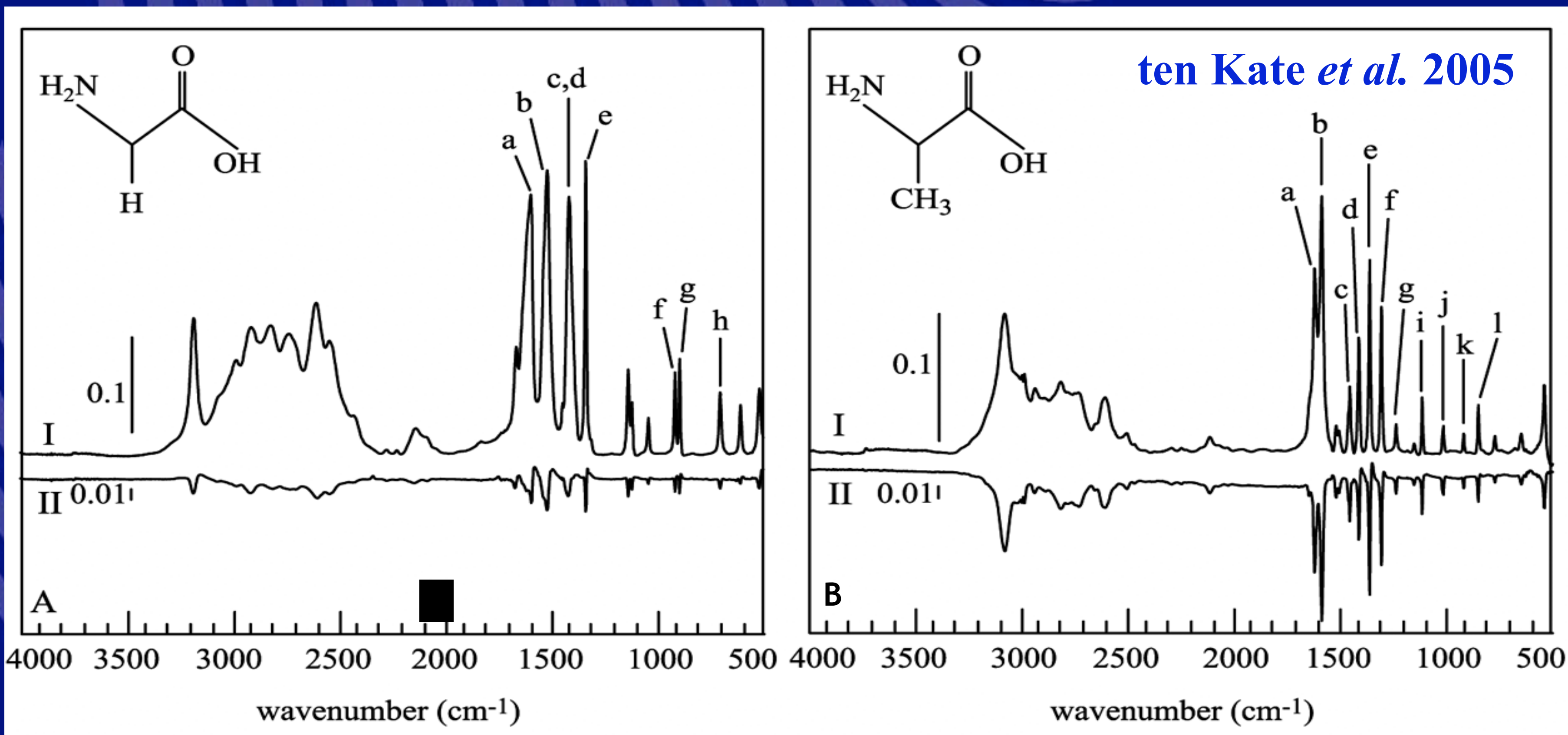
Leiden Institute of Chemistry & ESTEC





Glycine

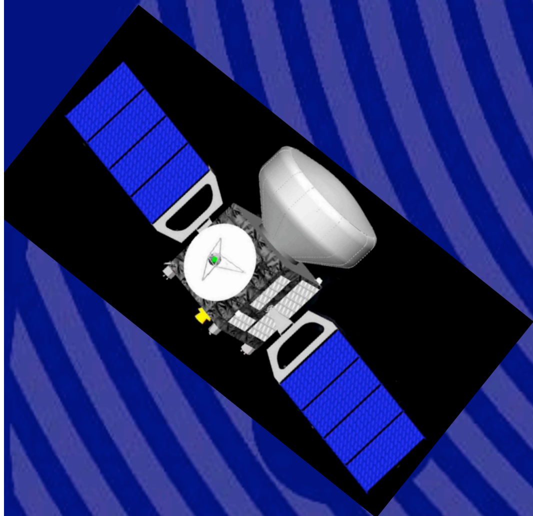
D-Alanine



I – Infrared absorption spectrum

II – Amount of material lost after 50 hours of UV irradiation

Aurora - European exploration program

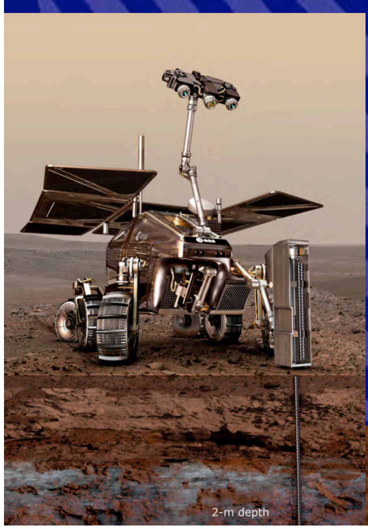


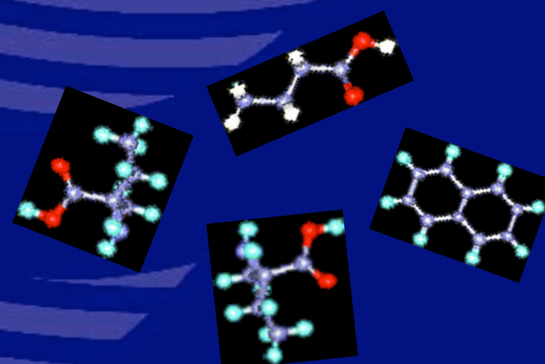
Exomars 2013

" Characterise the biological environment on Mars in preparation for robotic missions and then human exploration "

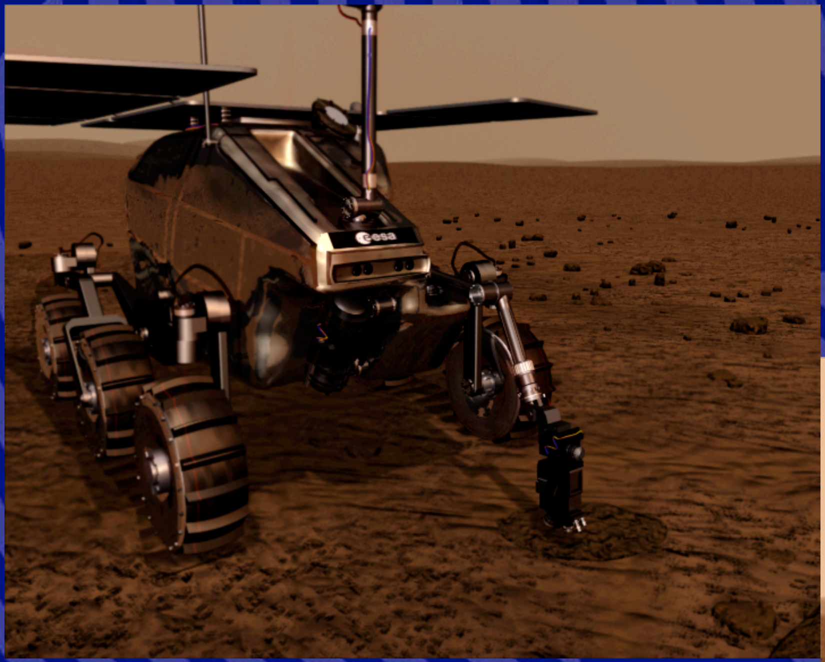
Instrument suite:

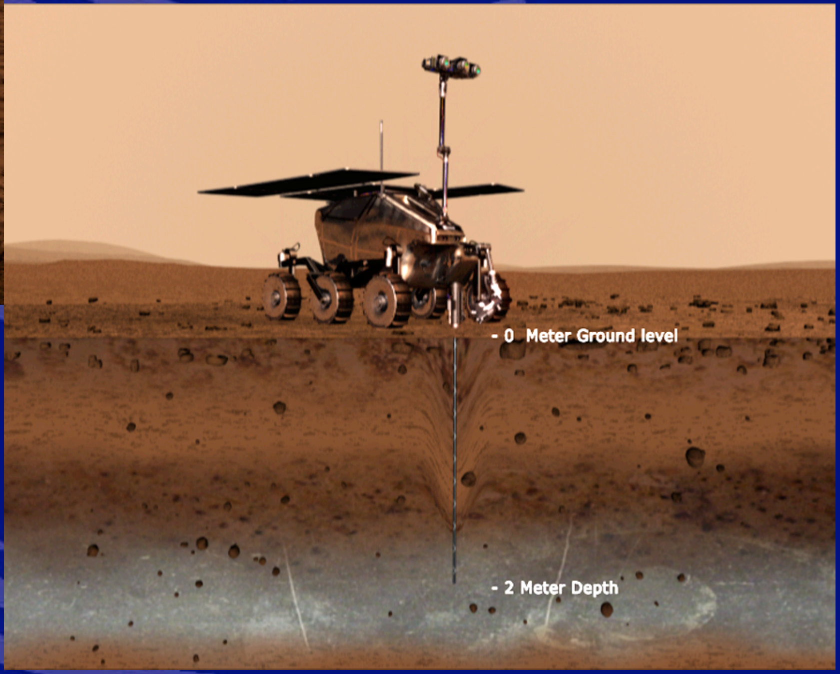
- **Mars Organic Detector - UREY**
- **AP-MALDI-GC/MS - MOMA**
- **Bioarray - LMC**





ExoMars 2013





In situ studies of cosmic dust, organics and ice on the Moon

- Non destructive capture of cosmic dust (passive capture collection/orbital parameters)
- Investigation of ice deposits at lunar poles
- Sampling of regolith and search for meteorites in different depths

Those investigation require robotic exploration techniques and/or human presence …

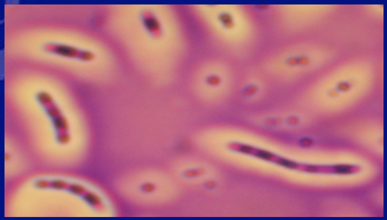
Astrobiology Laboratory on the Moon

Study of solar system samples in lunar treasure trove

- Cometary and meteoritic record
- Search for organics in regolith and polar ices
- Extinct/extant life in polar ices ? From Earth?
- Fossils of organics & ancient life from Early Earth

Expanding life beyond Earth

- Radiation exposure experiments
- Bacteria and extremes of life
- Botanic ecosystems
- Validation of life detection technologies
- Planetary protection issues



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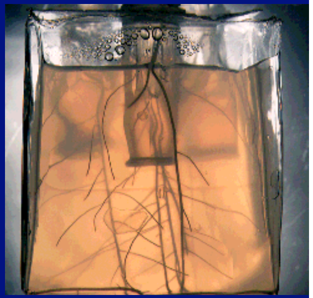
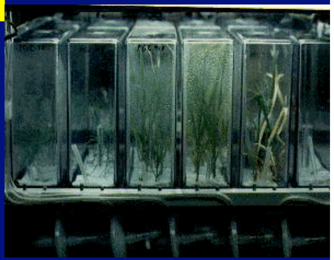
Expanding life beyond Earth



- Radiation environment and exposure studies
- Bacteria and extremes of life: Survival, replication, mutation and evolution
- Extraterrestrial botanics: Growing plants on the Moon (tulips, mustard Arabidopsis, Tagetes Petula, ...)



- Animals: physiology and ethology on another planet
- Closed Ecological Life Support Systems
- Greenhouses, Local Food Production

- Living off the land
- Support to human exploration
- Permanent human presence
- Biospheres on the Moon

- Planetary and environment protection issues
- Protection of Earth life (Noah's ark , DNA bank)

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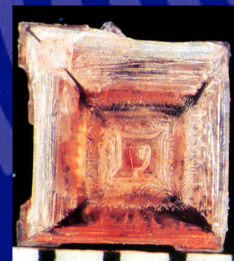
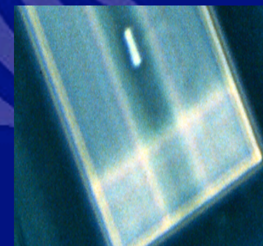
EXPOSE: Response of Organisms to Space Environment

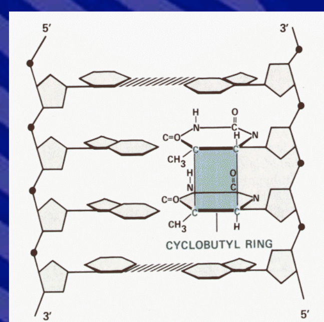


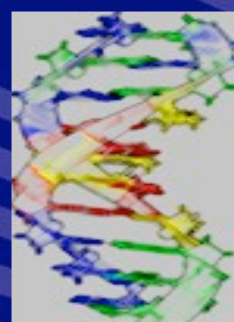
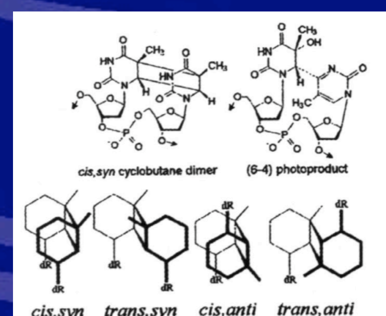




1. Investigation of the survivability of terrestrial organisms in space
2. Understanding of the organic chemistry processes in space
3. Contribution to the biological adaptation strategies to extreme conditions on early Earth and Mars

EXPOSE will give new insights to the origin of life and the chances and limits of life to be transported from one body of our solar system to another by natural processes.

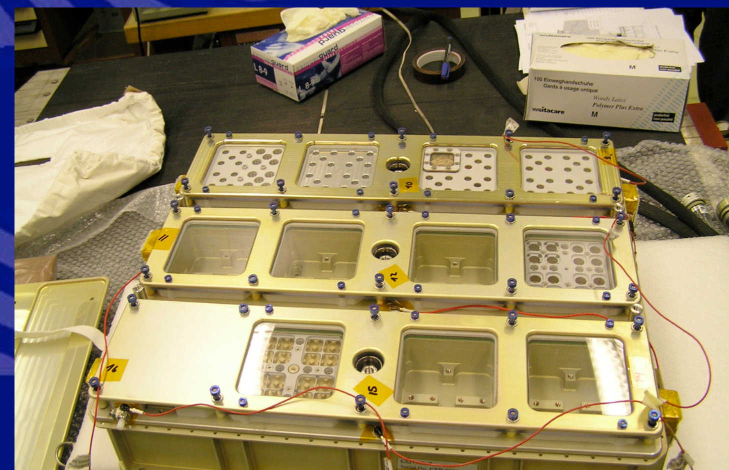


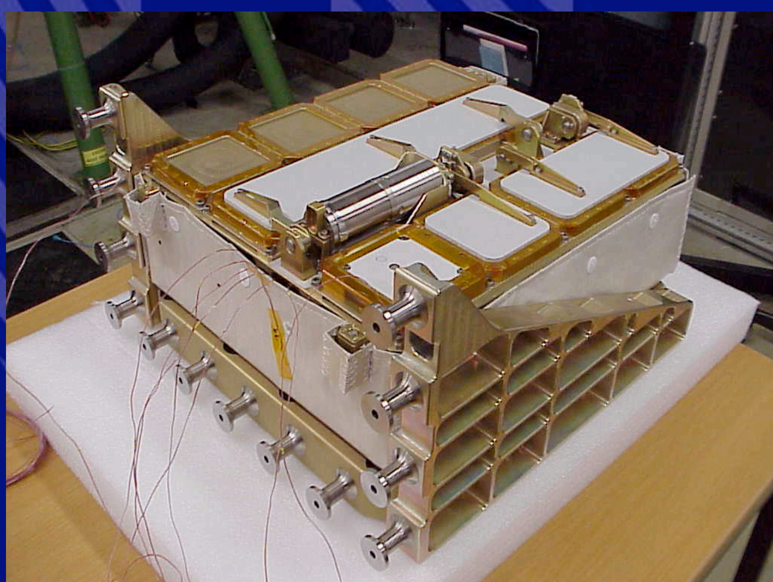


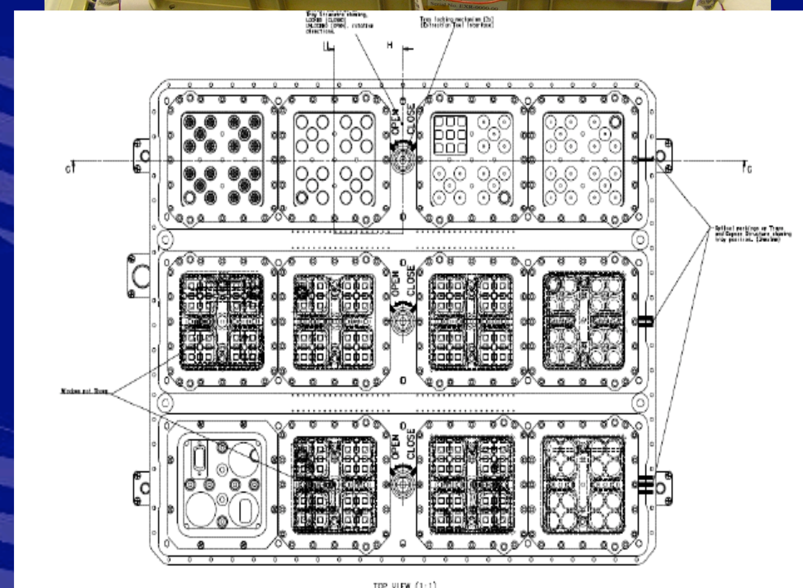



The EXPOSE Facility a European Facility for Astrobiological Studies in Earth Orbit -> possible adaptation to a lunar lander

- 3 Trays with 4 compartments each
- 11 either vented or sealed compartments
- 1 compartment with R3D Radiation Risk Radiometer-Dosimeter
- 3 different carrier types
- Lids for EXPOSE-E without lids EXPOSE-R



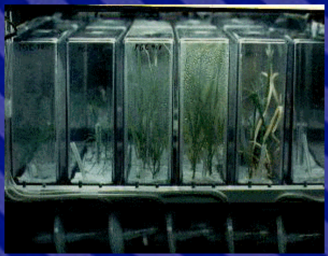


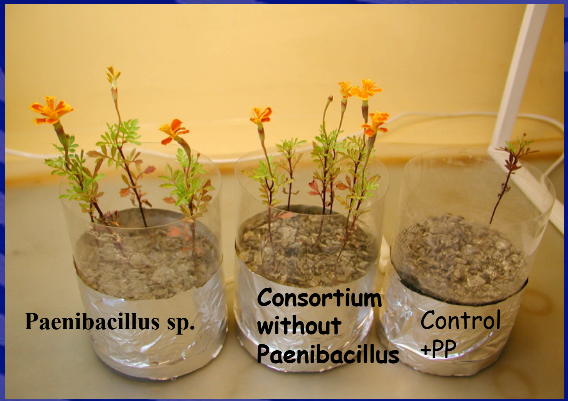


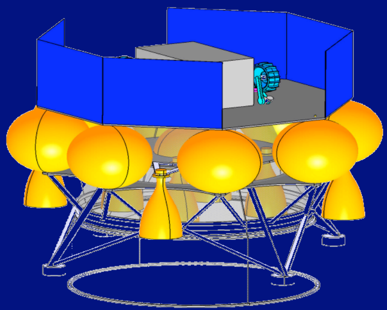
A precursor technology for growing first plants from lunar rocks in a lunar base

I. Zaetz (1), N. Kozyrovska (1), T. Voznyuk (1), I. Rogutskyy (2), O. Mytrokhyn (3), D. Lukashov (3), S. Mashkovska (4), B. Foing (5)

(1) Institute of Molecular Biology&Genetics of National Academy of Sciences, Kyiv, Ukraine, (2) Institute of Physics of National Academy of Sciences, Kyiv, Ukraine, (3) T. G. Shevchenko Kyiv National University, Kyiv, Ukraine, (4) Botanical Garden of National Academy of Sciences, Kyiv, Ukraine, (5) ESA Research and Scientific Support Department, ESTEC/SRE-S, Noordwijk, The Netherlands.







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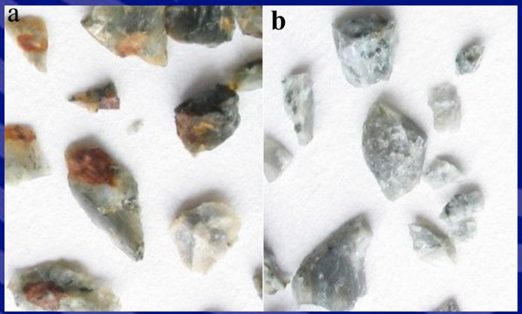
Growing pioneer plants for a lunar base

- Incrusted seeds of undemanding plants for germinating in a mineral substrate made from grinded local lunar-like material (anorthosite).
- Watering of seeds and seedlings periodically, without application of nutritional compounds:
- microorganisms provide the plant with essential minerals leached from the silicate substrate:

Zn^{+2} Mn^{+2} Fe^{+3} Cu^{+2} Ni^{+2} Ca^{+2} SiO_3^{2-} and

protect the plant from environmental stressors.



Paenibacillus corrosion of anorthosite rocks

- French marigolds in fragmented anorthosite of the Turchynka type.
- Two variants of microcosms inoculated with suspension of *Paenibacillus* sp. or a mixture of bacterial strains;

ESA ROLE IN THE ISS

Data Management for Zvezda
Launched Jul 2000

Microgravity Science Glovebox (NASA)
Launched Jul 2002

EMCS
Launched Jul 2006

Minus 80 degree Freezer (MELFI)
Launched Jul 2006

Node 2
Launch Oct 2007

Columbus
Launch 7 Feb 2008

2000

2010

Material Science Laboratory
Launch tbd

Crew Refrigerator/Freezer Rack (NASA)
Launch tbd

With payload racks

Fluid Science Laboratory

European Transport Carrier

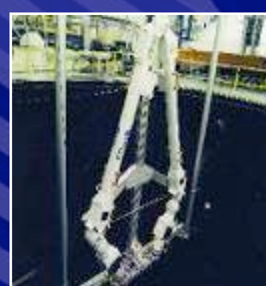
European Drawer Rack

Biolab

European Physiology Module

Node 3 (NASA)
Launch Jan 2010

Cupola
Launch Jan 2010



ERA
Launch Dec 2009

ATV
Launch 9 March 2008

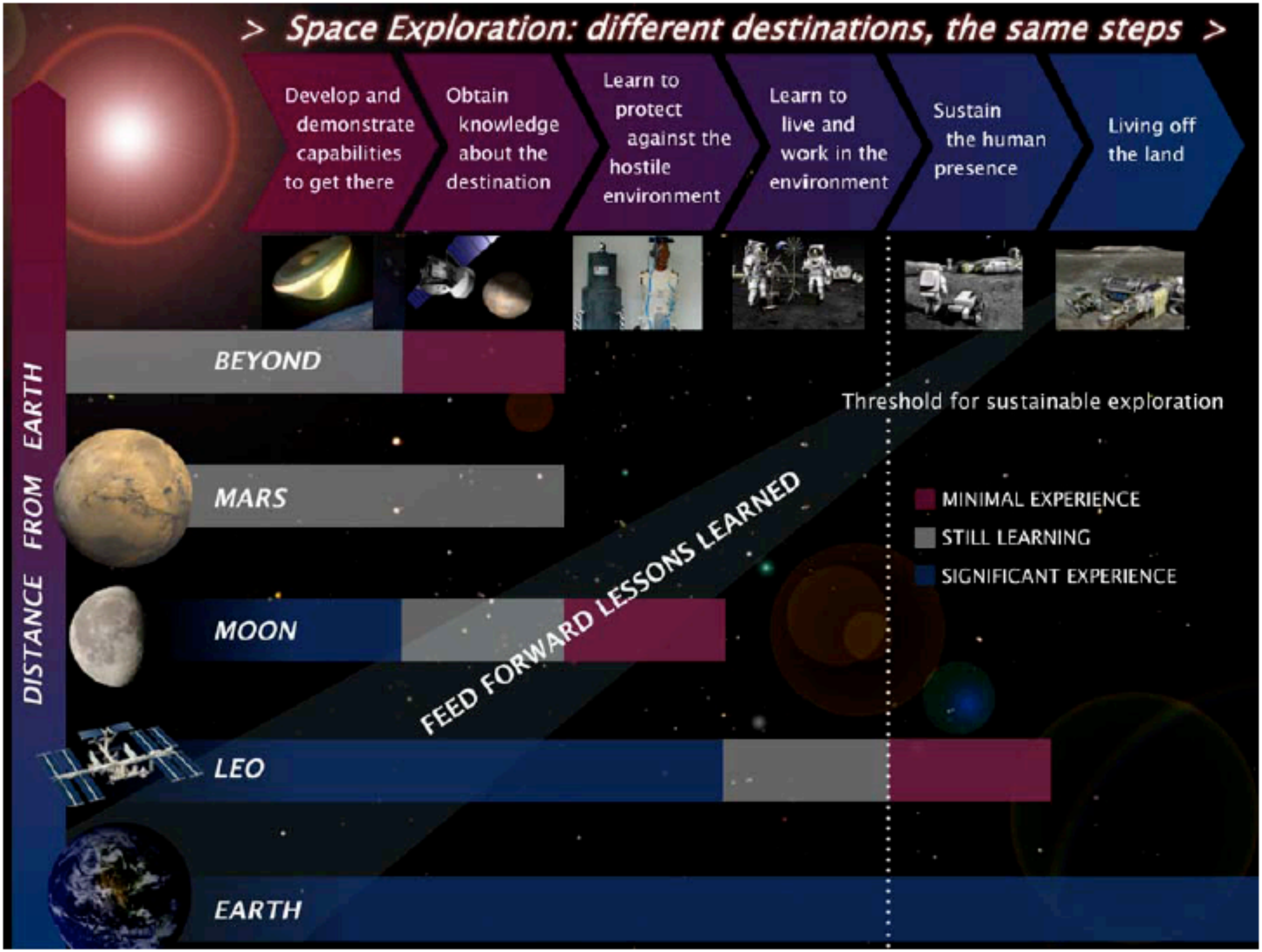
With external payloads

EuTEF

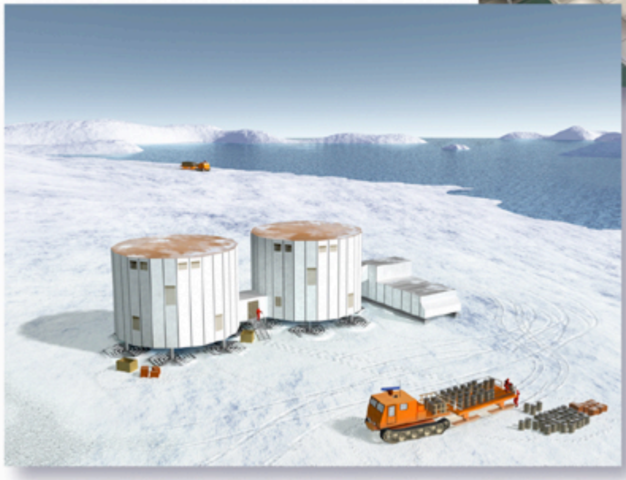
Solar

esa

BHF 2008



> Space Exploration: different destinations, the same steps >
Develop and demonstrate capabilities to get there
Obtain knowledge about the destination
Learn to protect against the hostile environment
Learn to live and work in the environment
Sustain the human presence
Living off the land
DISTANCE FROM EARTH
BEYOND
MARS
MOON
LEO
EARTH
FEED FORWARD LESSONS LEARNED
Threshold for sustainable exploration
MINIMAL EXPERIENCE
STILL LEARNING
SIGNIFICANT EXPERIENCE

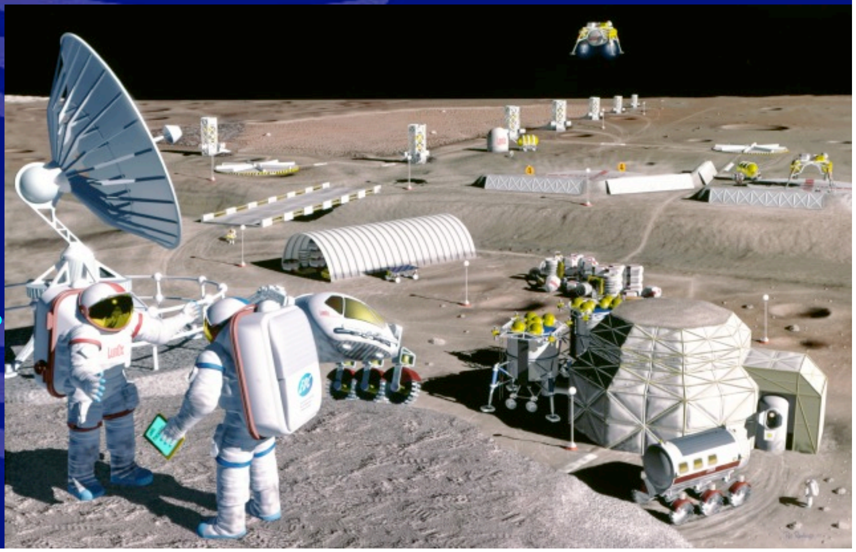


Extended human presence on the Moon

In order to build an infrastructure to enable humans to work on the Moon many astrobiological studies are required

Energy, Resources, Environment

- **extreme life**
- **hazardous radiation and high energy particles**
- **life support systems**
- **biospheres, greenhouses**
- **planetary protection issues .**



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BHF 2008

ILEWG ROAD MAP TO THE MOON VILLAGE, MARS AND BEYOND
(robotic, life sciences/Manned, Europe)

- MOON TECHNOLOGIES MARS

Setting an International Lunar robotic village and Mars robotic outpost

- 2010 Chang'E 1 orbiter II ISS exploitation Columbus, ATVs
- 2011 GRAIL+LADEE, Google-lunar X rovers Phobos Grunt
- 2012 LEO, Chang'e 2, Moon-LITE , Selene-B, lander
- 2013 IL Network , Maggia, ESMO plants, MELISSA, FEMME ExoMars , Mars Scout
- 2014 Infrastructures, energy, ISRU Network science
- 2015 Intl Lunar Robotic Global Village Scouts?
- CEV Crew Exploration Vehicle, ACTS
- 2016 ILN, Moon-NEXT point land, life sciences, biology lab Mars-NEXT

2017 ESA Logistics lander demo, Chang'E 3 sample return Astrobiology Field Lab?

International Lunar Base *Mars Exploration*

- 2019 Chinese mission to the Moon?
- 2020 ESA Logistics lander , US human on Moon
- 2021 Early Earth Sample Return?, European, Indian, Japanese on the Moon

Lab, Infrastructures, energy, ISRU, green house

- 2022 EMCRV Crew Return Vehicle ? Mars Sample Return
- 2023 Long Term Lunar Base >2030

Humans to NEO/Phobos

Humans to Mars

ILEWG Task Groups (2000 -) & NASA et al. themes 2006

- **Science of, on and from the Moon -> Scientific Knowledge**
  Pursue scientific activities that address fundamental questions about the history of Earth, the solar system and the universe - and about our place in them.

- **Technologies and Resource Utilisation -> New Technologies**
  Test technologies, systems, flight operations and exploration techniques to reduce the risks and prepare future missions to Moon, Mars and beyond.

- **Human Aspects, and Lunar Bases -> Human Civilization**
  Extend human presence to the Moon to enable eventual settlement.

- **Collaborative Roadmap & Moon-Mars Synergies -> Global Partnerships**
  Challenging, shared and peaceful activity that unites nations

- **Social, Economical Commercial, Societal Aspects -> Economic Expansion**
  Expand Earth's economic sphere, and conduct activities with benefits to home

- **Education Public Outreach & Young Lunar Explorers -> Public Engagement**
  To engage the public and youth students, and help develop the high-tech workforce required to address the challenges of tomorrow.